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Fe/Ni ratio in the Ant Nebula Mz 3

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Abstract. We have analyzed the [Fe II] and [Ni II] emission lines in the bipolar planetary nebula Mz 3. We find that the [Fe II] and [Ni II] lines arise exclusively from the central regions. Fluorescence excitation in the formation process of these lines is negligible for this low-excitation nebula. From the [Fe II]/[Ni II] ratio, we obtain a higher Fe/Ni abundance ratio with respect to the solar value. The current result provides further supporting evidence for Mz 3 as a symbiotic Mira.

Keywords. ISM: abundances, planetary nebulae: individual: Mz 3

1. Introduction

The Ant Nebula, Mz 3 is a young bipolar planetary nebula (PN) that consists of a bright core, two spherical bipolar lobes and two outer large filamentary nebulosities. In recent years, it has been extensively studied. There is evidence suggesting that Mz 3 is not a normal PN but contains a symbiotic pair at the center (Schmeja & Kimeswenger 2001). Zhang & Liu (2002) find that the dense nebular gas at the center may have a different origin from that in the extended lobes, and suggest that Mz 3 consists of a giant companion that gives rise to the central dense gas and a white dwarf that provides the ionizing photons. In the current study, we provide further supporting evidence for this scenario by determining the Fe/Ni abundance ratio in Mz 3.

2. Analysis

Our observations have been described by Zhang & Liu (2002). The slit was oriented approximately along the nebular major axis and through the central star. We divided the nebula into two regions. As shown in Fig. 1, [Fe II] and [Ni II] lines have been clearly observed from the central region, but are absent in the lobes, indicating a possible difference in chemical composition between the two regions.

Using the current available atomic data, we have constructed multilevel atomic models for Fe^+ (159 levels) and Ni^+ (76 levels), which were used to obtain the Fe^+/H^+ and Ni^+/H^+ ratios. For our calculations, continuum fluorescent excitation of [Fe II] and [Ni II] lines was also considered based on the method of Lucy (1994). However, we found that fluorescent excitation is not important in this PN given its low-excitation ($T_\star \sim 32,000\,$K) and high density at the center ($\sim 10^6\,$cm^{-3}). As shown in Table 1, the derived Fe^+/H^+ and Ni^+/H^+ ratios are almost independent of the dilution factor of continuum radiation, w. Given that Fe and Ni have similar ionization potentials, we assume $\mathrm{Fe/Ni} = \mathrm{Fe^+/Ni^+}$ in deriving the Fe/Ni abundance ratios.

3. Discussion

Iron serves as the dominant seed of *s*-process which occurs during the AGB phase. According to the AGB evolutionary models, iron in the envelop is diluted as material

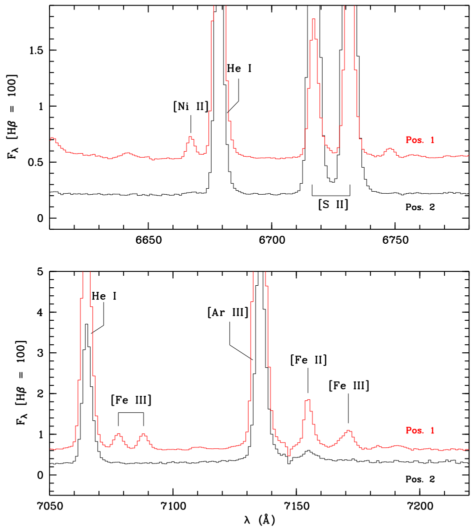

Figure 1. Spectrum of Mz 3 for a core emission region of nebular radii $r < 4$ arcsec (position 1) and an extended emission region consisting of the two bright inner lobes on either side of the central star between $4 < r < 15$ arcsec (position 2). [Fe II] and [Ni II] lines arise from position 1 but not from position 2.

Table 1. Fe/Ni ratio for the central emission region of Mz 3

w	0	10^{-3}
Fe^+/H^+	9.9×10^{-6}	9.2×10^{-6}
Ni^+/H^+	2.0×10^{-7}	1.8×10^{-7}
Fe/Ni[a]	50	51

[a]The solar Fe/Ni ratio is 18 (Lodders 2003).

is dredged up to the surface from the He innershell (the third dredge-up). Therefore, Fe/Ni ratio is expected to decrease after the thermally pulsating AGB phase. Fe and Ni have similar condensation temperatures, thus the amounts of depletion onto dust grains, if any, should be comparable. Therefore, Fe/Ni ratio in a PN should be lower than the solar value. From the deep spectra presented by Sharpee et al. (2004), we obtain an Fe/Ni ratio of 4.8 for PN IC 418, significantly lower than the solar value, consistent with the predictions of the AGB models.

However, no significant depletion of the Fe/Ni ratio is detected for the central dense emission region of Mz 3, as shown in Table 1, suggesting that the gas arises from winds of a giant companion where the *s*-process has not occurred yet. Our results show an enhancement of the Fe/Ni ratio relative to the solar value and we attribute this to a slightly higher depletion of Ni relative to Fe.

References

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